IAG-AIG WORKING GROUP
SMALL CATCHMENTS

INTERNATIONAL SEMINAR OF THE IAG WORKING GROUP ON SMALL CATCHMENTS

GEOMORPHOLOGY
GEOMORPHOLOGIE

Międzyzdroje, 22-23 April 2008

International Association of Geomorphologists
Institute of Paleogeography and Geoecology, Adam Mickiewicz University
Chief Inspector of Environmental Protection
Wolin National Park

SEMINAR PROCEEDINGS

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Foreword

River catchments are an important landscape structure in all morphoclimatic zones of the Earth. They are an object of both specialised and all-embracing, often interdisciplinary, studies. A river catchment is a structure of the surrounding space that we can conventionally term a geoecosystem. Adopting the phrase 'river geoecosystem' has methodological implications as to its internal structure, operation, and connections with the neighbouring landscape structures.

What distinguishes the Small Catchments programme among many fluvial programmes currently implemented is a search for index features of the operation of a catchment that can help to determine present-day landscape changes in the various morphoclimatic zones. The meeting of the IAG's Small Catchments working group on Wolin Island is intended to achieve the following:

- ✓ presentation of river catchments selected for the programme,
- ✓ adoption of guidelines for the description of the current state of catchment operation as a basis for the planned publication, and
- ✓ selecting the members of the working group and drawing up a working schedule.

It is my belief that the meeting on Wolin Island, in the Wolin National Park, will be a good start of our co-operation in seeking a deeper insight into the mechanisms of operation of small river catchments in both a theoretical and a practical aspect.

Andrzej Kostrzewski
Programme coordinator

ABSTRACTS

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Small catchments programme: object of study, methodological and organisational assumptions

Introduction

Landscape structures undergo constant changes and transformations on the Earth's surface under the influence of both, natural and man-made processes. Capturing the character of those changes is of key importance for our understanding of the operation of present-day geoecosystems. A research programme should embrace diagnostic and forecasting studies. River and lake catchments are spatial units useful for an identification of contemporary changes in the Earth's surface.

The Small Catchments programme is intended to provide documentary material for comparative studies of index features of changes in landscape structures in various morphoclimatic conditions.

Methodological assumptions

The object of study in the Small Catchments programme is river and lake catchments, for which we adopt the term geoecosystems. To understand their operation, it is necessary to carry out qualitative and quantitative research on energy and matter changes that occur in them, and to grasp their relations with the neighbouring elements, subsystems and systems.

Of fundamental importance from the methodological point of view is the determination of the internal structure of river and lake geoecosystems and their controls (geographical location, geological structure, relief, climate, water cycle, soils, vegetation, and land-use pattern).

Basic objective of the programme

The basic objective of the programme is to capture the uniqueness of operation of small river catchments situated in a variety of morphoclimatic conditions. The study of the geoecosystem of a small river catchment embraces the identification and determination of its environmental controls, internal structure, supply sources, and the pathways of circulation and outflow of energy and matter in the conditions of climate change and multi-directional human impact. Defined in those terms, the operation of small river catchments can provide a basis for determining their uniqueness in various morphoclimatic zones and for working out a programme of their protection and conservation in the world's landscape structure.

Methods

The research on the operation of river and lake catchments should rest on a standardised field measuring system. The programme should embrace multi-year monitoring of the greatest possible number of geoecosystem elements, collecting the data in thematic bases, and their analysis. An important index feature of changes in present-day river and lake geoecosystems is the type and dynamics of fluvial transport (dissolved, suspended and aeolian load, variations in the morphology of river channels, and human impact).

Basic research tasks

The adoption of the conception of operation of small river catchments allows the following research tasks to be formulated:

- ✓ determining the internal structure of a catchment on the basis of the assumptions adopted: the geological structure, relief, hydro-meteorological conditions, land use, etc.;
- ✓ organising a measuring system in order to carry out an integrated monitoring of the natural environment of the catchment (weather conditions, hydrometric cross-section closing the catchment, subterranean waters, etc.);
- ✓ water sampling (the cross-section closing the catchment, subterranean waters, springs, etc.) to determine supply sources, circulation pathways of matter, as well as mechanical and chemical denudation;
- ✓ monitoring extreme processes and their effect on the operation of the catchment;
- ✓ identifying the geodiversity of the catchment, choosing sites for protection;
- ✓ identifying changes in the landscape structure of the catchment on the basis of available land-use maps;
- ✓ developing a thematic database; and
- ✓ simulation and forecasting studies.

Organisational assumptions

The basic assumption of the programme is comparative studies of river catchments in various morphoclimatic zones. The results will be presented and discussed at working meetings, and published in selected journals. We are planning to publish the programme's assumptions, together with the presentation of the catchments involved, in Quaestiones Geographicae, an Adam Mickiewicz University journal appearing in English.

Organisation of the research, planned initiatives:

- ✓ selection of a river catchment up to 100 km^2 in area, which can be part of a larger river system;
- ✓ continuous observations of weather conditions at a weather station;
- ✓ installation in the catchment of a network of piezometers to identify the pathways of groundwater circulation and outflow;
- ✓ a hydrometric cross-section closing the catchment with a daily record of water stages and water sampling to calculate the concentrations and loads of dissolved and suspended matter;
- ✓ observation and registration of extreme events and their effect on the operation of small river catchments in the conditions of climate change and growing human impact;
- ✓ presentation of a conception of a network of small river catchments in various morphoclimatic zones on the basis of the adopted assumptions of geoecosystem operation;
- ✓ working meetings (a paper session) as part of conferences of the International Association of Geomorphologists and submission of the papers for publication; and
- ✓ preparation, for the International Conference on Geomorphology in Melbourne, 2009, of a monograph on Small river catchments and their significance in protecting the landscape structure of the Earth's surface.

Summing up

The river catchment programme is interdisciplinary in nature and should rest on a multi-year research. On the conference In Melbourne we will present a proposition of prolongation of the activity of our group.

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Geological-environmental researches and soil erosion monitoring in the Rivo catchment (Molise, Southern Italy)

Molise is one of the Italian regions which is strongly characterised by a rural environment and related economically important agricultural activities, but also by a high degree of geomorphologic hazard and risk due to mass movements and erosion by running water.

To understand the relationships between geological-environmental features and morphodynamics and the effects of the latter on slope stability and soil loss, we have developed a number of research activities in Molise and implemented on particular a monitoring system for soil erosion. The study area is represented by a little tributary basin of the Trigno river which, thanks to its main geological-environmental features, is very representative for the hilly to low mountainous sectors which characterise large portions of the Molise territory. This basin is drained by the Rivo torrent, a 6th order stream, and extends for about 80 km^2.

Direct measurements on soil erosion are currently performed in the headwater portion of the Rivo basin. The selected test area (22.5 km^2) is composed of three major sub-basins of 4^{th} and 5^{th} order and is instrumented for the continuous measurement of climatic parameters and of solid and liquid discharges. The measurements of soil loss at a test plot scale are carried out in the *test plot station of Morgiapietravalle* which is located near the main water divide and implemented with three permanent plots with different land use. The there located weather station provides data on rainfall, wind speed and direction, air temperature, and is integrated by other two rain gauges located outside the test area in the Rivo basin. At the catchment scale, liquid discharges and solid transport are measured at the outlets of the monitored sub-basins and at two minor outlets located inside of one of them.

The data on soil loss collected within the test plot station during the last seven years show that soil erosion rates have rarely exceeded 1 t Ha^{-1} per year, a value which is consistent with the theoretical values of tolerable soil loss on farmland. This can be attributed to the fact that the tested soils are characterised by a high permeability, as confirmed by direct measurements of saturated hydraulic conductivity, as well as by the discharges measured at the outlets of the monitored sub-basins.

Despite the low soil loss rates, chemical and physical analyses carried out on soils in the test area confirm the presence of numerous evidences of accelerated soil erosion, such as the lack of an organic soil layer (O) and the presence of a thick anthropic horizon (Ap), as well as a high superficial density and significant amounts of calcium carbonate in the topsoil. The analysis of a soil “catena”, oriented transversely to the main stream incision, allowed to evidence the strong influence of topography on erosive processes and, consequently, on the main physical and chemical properties of soils, as well as to confirm the accelerated erosion in most of the observed soils.

Collected experimental data have allowed us to calibrate and validate different models for the prediction of soil erosion and for the calculation of surface runoff. The experimental results encourage us to develop new methods to improve the consistence between experimental data and the results obtained from predictive models.

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Conform model USLE to automatic mapping intensity of soil erosion in the Bystrzanka mountain catchment (Flysh Carpahtian)

This paper was presented the results of modelling of soil erosion processes in Flysh Carpathians. Analysis was based on Universal Soil Loss Equation (USLE) by Wischeier and Smith. Geographical Information Systems programs were used to modelling. Empirical area was slopes of the Bystrzanka Catchment (on the borderland Carpathian Foothills and Beskid Niski Mountains). Components of USLE model were counted on the basis of 23 years meteorological observations to describe rainfall and runoff factor (factor R), the metod of H. Mitasowa (1999) to describe topographic factor (factor LS), land cover map to describe support practise factor (factor P) and long term observations of soil erosion on experimental fields in Research Station of the Institute of Geography and Spatial Organization of the Polish Academy of Sciences in Szymbark.

Result whose was received from USLE model was 2,5 times as many than value of soil losses on the experimental slopes. It just was gone to show that USLE was needed modifications to use correctly in Polish Carpathian Foothills.

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Monitoring hydrology and sediment transport in a Mediterranean agricultural catchment (Mallorca, Spain)

One of the most representative agriculture elements of Mediterranean-climate regions is rainfed herbaceous crops. Can Revull is a small catchment (1.03 km^2) in the island of Mallorca covered in a 91% by this land use. Geology is characterised by gentle structurally alpine relieves in the Central Ranges of the island composed by carbonate rocks. Average channel slope is 4.7% (10% first 400 m and 2% remaining 2 km). Climate can be classified as sub-dry Mediterranean, with a mean temperature of 16.5ºC, a mean annual rainfall of 517 mm, and a Potential Evapotranspiration of 1,010 mm. The hydrological regime is intermittent with a mean annual discharge of 4.1 $l\ s^{-1}$. Subsurface-tile drainage was constructed in a 75% of the catchment due to deep soils, concave low plain topography and very humid winters. The steep and convex topographical areas are terraced by dry-stone walls. A gauging station was constructed at the catchment outlet in December 2003, using a sharp crested thin plate weir (90º V-notch). Water stage, turbidity and conductivity are continuously measured. Additionally, rainfall is recorded using a tipping-bucket Davis rain gauge.

Three hydrological years data between 2004 and 2007 were analyzed, emphasizing that hydrological functioning is conditioned by PET and water-storage capacity. The first one was the most influential variable on annual and seasonal time-scales, generating a succession of three different hydrological periods. In addition, it played an important role in baseflow dynamics originally controlled by the high field capacity of clay soils; they generated significant reservoir volumes for runoff, but were drastically reduced with just slight PET increments. The second one explains the high annual runoff coefficients (24.8%) and the high value of BFI (0.92). Both are enhanced by subsurface-tile drainage. Moreover, water-storage capacity exerted a control over quickflow response since this capacity has to be complete before any significant runoff is generated.

During the same period, a detailed study of suspended sediment transport and related processes highlights strong seasonal contrasts of baseflow dynamics are associated to different degrees of dilution. As a result, these dynamics provided an important scatter in SSC and in derived rating curves reflecting that another factors control the supply of suspended sediment to the stream. Multiple regression analysis shows that rainfall intensity was the most significant variable in sediment supply. But also when baseflow was present, physical and biological processes generate sediment in stream which is easily removed by flushing operation. Meanwhile, when baseflow was not present, only rainfall intensity is the variable that supplies sediment to stream mostly from bare slopes. Finally, traditional soil conservation measures contribute to make a somewhat different the studied catchment in terms of sediment transport in Mediterranean rivers since suspended sediment yield (3.1 $t\ km^{-2}\ yr^{-1}$) tend to be at least an order of magnitude less than for most other studied Mediterranean climate basins.

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The Homerka instrumented catchment

The work reported in this contribution was undertaken in the Homerka instrumented catchment in the Polish Flysch Carpathians, where a combination of conventional methods of monitoring soil erosion, sediment transport and overbank sedimentation and novel sediment tracing techniques have been applied over the past 35 years.

The 19.6 km^2 catchment of the Homerka stream lies at an altitude of 375–1060 m a.s.l and is representative of the partly deforested landscape of the Polish Flysch Carpathians The area is characterized by highly active erosion, sediment transport and fluvial sedimentation processes. The catchment has a mean discharge of 0.362 $m^3 s^{-1}$, a mean annual flood discharge of 9.15 $m^3 s^{-1}$, and a mean annual rainfall of 928 mm. Extreme floods, with peak discharges in excess of 3 $m^3 s^{-1} km^{-2}$, exert an important control on the fluvial system and are highly significant as geomorphologically effective events. The area is characterized by rapid flood generation, significant soil erosion, and high suspended sediment loads. The high annual suspended sediment yield of the Homerka catchment is approx. 550 t km^{-2} $year^{-1}$ and suspended sediment concentrations during floods may exceed 3×10^4 mg l^{-1}. The critical threshold for the widespread occurrence of dispersed overland flow is a storm rainfall of approx. 20 mm with a minimum intensity of approx. 1 mm min^{-1}.

The Homerka catchment comprises two main zones, representing the montane headwater and the lower foothill zones. The headwater areas, which are predominantly forested, are characterized by steep (15–35°) convex and straight slopes and shallow permeable skeletal soils. These forest areas, which account for 52% of the total basin area, are dissected by a dense network of unmetalled roads and lumber tracks.

The foothill zone lies below 650 m a.s.l. and this part of the drainage basin is underlain by shale-sandstone flysch series and is characterized by more gentle slopes (5–15°). The silt-clay soils support small traditional farms and the associated mosaic of arable fields is bounded by agricultural terraces and crossed by a dense network of unmetalled roads, which are commonly sunken below the level of the surrounding land. The valley floors of the third order streams are flat, covered by alluvium and occupied by meadows and permanent pasture. In this lower zone of the catchment, most of the stream channels are not in direct contact with the slopes.

Unmetalled roads are a characteristic feature of both the Carpathian landscape in general and the Homerka catchment in particular. They date back to the original clearing and cultivation of the land. The network of roads serving the fields is related to the field pattern. Major roads tend to be located along both watercourses and divides and are linked by a dense network of secondary roads, which run downslope or at an inclination to the slope. In narrow valley bottoms, unmetalled roads often run along stream channels, which in forest areas are often used for log transport. The density of unmetalled roads within the catchment as a whole is 5.3 km km^{-2}.

In order to permit detailed investigation of erosion and sediment delivery from a representative cultivated zone in the lower part of the basin, an area of 26.5 ha located on the boundary between the forest and the agricultural areas has been designated an “experimental slope”. The slope is 500–700 m long and convexo-concave in form. The silty clay soils increase in depth towards the base of the slope. The plots are separated by terraces and ditches and by the unmetalled roads, which traverse the area from the watershed to the stream channel. During times of heavy rainfall, these unmetalled roads act as channels for surface runoff and in many places they are deeply incised into the slope. The length of unmetalled road traversing the experimental slope is 3.3 km, equivalent to a density of 11.9 km km^{-2}.

Each of the main subcatchments in the Homerka catchment and the catchment outlet are gauged and measurements of runoff and sediment load have been undertaken since 1971.

These measurements have been complemented by other more targeted measurements, aimed at estimating erosion rates and slope–channel sediment transfer. The application of $^{210}Pb_{ex}$, ^{7}Be and ^{137}Cs to studying sediment mobilisation, main sediment sources, sediment delivery dynamics and sediment budget began in the catchment in 1984.

Suspended sediment sources within the Homerka catchment have been investigated using the "fingerprinting" approach, with $^{210}Pb_{ex}$, ^{7}Be and ^{137}Cs providing the primary source fingerprint. Sediment samples collected from individual flood events have been used to identify the primary sediment source, because sediment transported during different storm events may originate from various sources with different radionuclide signatures. Sediment mobilised by diffuse surface flow from the surface of areas under forest, permanent pasture and cultivated fields will have a significantly higher radionuclide content than that mobilised by linear flow from unmetalled road and gullies. The contribution of surface (i.e. hillslope) and subsurface (i.e. channels, roads and gullies) sources was assessed based on the activity of the fallout radionuclides $^{210}Pb_{ex}$, ^{7}Be and ^{137}Cs, which are concentrated in surface soil. Sediment mobilised from hillslope sources by diffuse surface flow will be characterized by relatively high concentrations of these radionuclides, whereas that eroded from gullies or channels will have a much lower or zero fallout radionuclide content.

The study reported confirms the ability of the conjunctive use of the $^{210}Pb_{ex}$, ^{226}Ra, ^{7}Be and ^{137}Cs to provide additional information on sediment mobilisation and sediment delivery during high energy floods within a small drainage basin in Polish Flysch Carpathians. The depth distribution of $^{210}Pb_{ex}$, ^{226}Ra, ^{7}Be and ^{137}Cs in undisturbed soils can provide a means of establishing the depth of surface erosion during different high magnitude events. An understanding of the relationship between erosion, sediment redistribution and storage and sediment transfer in mountain headwater areas requires information on the various pathways and linkages within the fluvial system. The main problem of sediment management is to identify linkages between the sediment source and the stream channel and sediment delivery dynamics during high magnitude events. During extreme storm events, the contributing area is greatly expanded and sediment is mobilised from areas, which are unconnected to the stream during 'normal' events. However, there is a lack of field evidence to document the main sediment sources and the sediment delivery dynamics during individual high magnitude floods.

Bed load transport has been measured using both acoustic and magnetic techniques. The passive acoustic method permits continuous measurement and is able to provide a continuous record of coarse particle movement during flood events, which is a direct reflection of the magnitude of bed load movement. Coarse material bed load transport has also been measured using magnetic tracers. In this case, magnets are cemented into holes drilled into gravel particles and an electromagnetic sensor is used to track their movement through a designated short reach. In addition, transport distances associated with individual gravel particles tagged with magnets during individual events have been documented by recovering the labelled gravel after the event using a metal detector. These magnetic tracing techniques permit the bed load transport rate associated with individual grain size fractions to be quantified.

The improved knowledge of sediment sources and sediment delivery dynamics within the study area provide a valuable basis for developing improved sediment control and management strategies aimed at reducing rates of reservoir siltation.

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Delivery of matter to the floor of a *Luzulo pilosae Fagetum* forest community in the catchment of Lake Gardno (North-Western Poland, Wolin Island)

There are three main sources supplying matter to the geoecosystem of the Lake Gardno woodland catchment. The first is dissolved matter contained in precipitation, throughfall and stemflow. The second is the beddingfall and the third is mineral eolian matter. The analysis of the chemical composition of precipitation and its hydrochemical indicators makes it possible to determine the extent of its similarity to the composition of sea water. The similarity, in turn, is a function of the content of marine aerosols in the atmospheric air. High values of the sodium/chloride indicator are associated with high concentrations of those aerosols. The variability of the indicator confirms that the marine influence can be traced first in the dissolution of sea salt in precipitation, and then in its deposition on the bark and leaves. The sodium/chloride indicator is more reliable for throughfall and stemflow than the combinations with magnesium and potassium, which can be partly of organic origin. An analysis of the correlation between the sum of velocities of winds blowing from the sea and the load of particular ions on the forest floor has shown the frequency and velocity of onshore winds to have a significant effect on the loads of Cl^-, Na^+, Mg^{+2} and SO_4^{-3} delivered to the catchment. The loads of hydrogen ions reaching the forest floor show variability correlated with the vegetation season. With the start of the beech growing season in April, the adsorption of hydrogen ions can be observed. The buffering ability of assimilation organs persists throughout the entire season, reducing the number of protons reaching the forest floor even by 99%. The effect is a substantial enrichment of water solutions getting to this part of the forest in potassium, calcium and magnesium loads. The volume of proton loads delivered to the forest floor in the non-growing season is more than 16 times greater.

The beddingfall deliver to the catchment most of all nitrogen, phosphorus and calcium. Average of yearly eolian accumulation is greater on the edge of cliffs and achieve 4,8 mm. Average of yearly eolian accumulation in the catchment achieve only 0,01 mm.

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River Tame Study Catchment details, including instrumentation

This study was focused on the Wolverhampton arm of the main upper River Tame, West Midlands, UK (Figure 1). The Tame flows into the Trent which is a major contributor to the Humber estuary (Jarvie et al., 2000), one of the most important estuaries in the UK. The Tame is the most urbanized basin in the UK (42% urban at Bescot downstream; Webster et al., 1999), and the headwater basin here is almost entirely urban (c. 75%), except for a few small playing fields, parks and other open spaces. The basin drains part of Wolverhampton, Walsall and the 'Black Country' which has a long history of coal mining, metallurgical industry and steel working (Elliott, 2000). Indeed, the upstream end of one of the Tame tributaries, the Darlaston Brook, intercepts mine shafts, which effectively extends the catchment area beyond the topographic divide (Jarvie et al., 2000). The Tame also receives inter-basin water transfers from mid-Wales (Petts and Wood, 1996).

Once one of the most polluted rivers in Europe, its current quality trajectory shows gradual improvement (Severn Trent Water Authority, 1976; Dempsey et al., 2003). The Upper Tame quality is placed in the worst category, RE5 (River Ecosystem 5: highly polluted), and 'generic urban' class by Jarvie et al (2000), with strong metallurgical industry impacts (predominantly nickel and chromium), and with very high mean river water concentrations of NH4, Cl, AAP-Ni, AAP-Cr and Diss-Ni. The headwater area chosen here was assigned to the highest priority class for study and investment under the Severn-Trent Tame Urban Pollution Management (UPM) study (Dempsey et al., 2003). Jarvie et al (2000, p. 36) refer to diffuse pollution sources here as 'roads, factory yards, contaminated land, industrial sites, spoil heaps, and mineworkings and combined sewer overflows (CSOs)'. The contaminated land component is widespread (Elliott, 2000). The Tame may also receive effluent from point sources such as wastewater treatment works (WwTWs) and industrial sites (Halliday, 1986; Crabtree et al., 1999; Dempsey et al., 2003).

Around 80% of dry-weather flow is considered to be effluent discharge (NRA, 1996; cited in Jarvie et al., 2000). The basin also contains a mixture of mature residential areas, and mainline railway, canal and major motorway networks, including the M6 which runs north-south to the east of the James Bridge gauging station (Figure 1).

Most measurements reported in this paper have been captured by the UK Environment Agency river flow and automatic water quality monitoring station at James Bridge, Bentley Mills, near Walsall (UK National Grid Reference SO 990 975). The basin area at this point is 57 km^2, and station altitude is 113.3m above O.D. (Ordnance Datum). There is one major WwTW in the headwater basin, at Willenhall, which lies ~1.5 km upstream of James Bridge. The urban drainage network contains a mixture of semi-natural stream channels, canalized or heavily modified channels, culverts, sewer networks, outfalls from sewage treatment works, CSOs (Combined Sewer Overflows) and gully pots (catch basins). The Black Country Trunk Sewer (BCTS) diverts some wastewater away from the Tame system (Dempsey et al., 2003). Booker (2003) found that the heavily modified reaches of the Tame downstream of James Bridge produced extremely high, ecologically-limiting, stream velocities during storm events.

Monitoring Methods. Automated continuous monitoring at James Bridge allowed 15-minute data to be collected on discharge, turbidity and five other water quality variables (electrical conductivity (EC), temperature, pH, DO and ammonia (NH3 (N)). The station at James Bridge was re-established in March 2001. For this paper, ammonia data for spring

2001 are taken from Water Orton, ~28km downstream, as the James Bridge ammonia sensor was not deployed till June 2001. Water samples for quality monitoring were pumped up from the river to a nearby measurement facility from an intake located on the right bank of a relatively straight reach. The instrumentation system was cleaned and maintained at approximately weekly intervals. Turbidity was monitored with a pHOX 750M absorptiometric turbidity head (Phoenix Instrumentation Ltd), functioning as in-line probe housed in the riverside measurement facility, and so was not affected by snagged debris or detrimental mechanical impacts as many in-stream sensors are. Turbidity was measured across a 50mm gap using a visible light source (red LED) in the instrument, which was connected to an interrogable automatic data acquisition system. The optics were automatically cleaned five teams per hour with mechanical wiper blades, with additional manual cleaning at weekly intervals. Zero drift was checked approximately weekly, and end-point calibrations were performed at approximately monthly frequency, following thorough instrument cleaning, using deionised water and a liquid turbidity standard of 500 FTU (Formazin Turbidity Units): see Lawler (2004). A few breaks in record resulted from occasional system malfunction, but these did not affect the events studied here. A new 15-min precipitation data series has been generated here from the 1-minute dataset maintained at the University of Birmingham station at Winterbourne, 14km southeast of James Bridge. The focus of this paper lies solely with the storm events of spring 2001, using the UK Meteorological Office definition of spring as March, April and May.

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Processes modelling the highly elevated upper Skawica River flysch catchment, Babia Góra massif (620-1725 m a.s.l.)

Large water resources and deep water circulation covering a large area influenced by landslide morphology are the basic hydrological features of the upper Skawica River catchment, area 48,6 km^2, covering the northern slope of Babia Góra massif (620-1725 m a.s.l.) in Polish Western Beskidy Mountains. The investigations cover the highest located catchment in this area built of nonkarstifying rocks. The mean water outflow exceeds locally 35 $l\ s^{-1}\ km^{-2}$, the outflow coefficient reaches extremally high value as for the Western Beskidy Mounatins conditions, exceeding 85%. A passive hydrological season lasts at the subtop area of the catchment even half a year, when thick snow cover accumulates. While during the active hydrological season intensive charge of watercources by melt waters and later by precipitation occurs. Hence, the streams have changing flow rate during the year, but their increased charging by underground water reduces fluctuation of their flow rates. The large amounts of underground water accumulates in deeply fissured Magura sandstones and in the thick layer of colluvial debris. The network of streams within the catchment is dense and they are mostly charged by underground outflow. The occurence of three hydrological altitudinal zones is a unique feature of the catchment. They are: the highest located zone of water alimentation in the deeply fissured Magura sandstone, the water transition zone in the slope covers and the zone of water accumulation in the alluvia. The highest hydrological altitudinal zone determines water resources in the whole catchment.

The author's long-term investigations of thermal conditions of the springs enable to determine the depth and time of water circulations within the catchment, while the analysis of chemical composition of waters from springs and streams allows to estimate the size of dissolved load outflow and to determine the tempo of formation of subsurface rock hollows, which are compressed by mass movement. Subsurface chemical denudation within the catchment studied affects development of surface forms of the relief typical for deep structural landslides, but it does not cause any phenomena typical for karst regions. In result of intensity of slope processes estimation, it has been found that the most intensive removal of rock masses occurs as ionic transport. Subsurface chemical denudation also affects internal desintegration of bedrock, which makes rock movements on slopes easier. Due to that process, major morphological contrasts on the slopes of a concave profile are deepended, and the general morphological contrasts on the slopes of convex-concave profile are smoothed due to the greatest removal of rock mass from the convex parts of the slopes. The lesser chemical denudation rates in the uppermost part of the catchment situated in the cryonival belt is compensated by a stronger activity of gravitational movements in the area. Considering the slight retention ability of the bedrock, the chemical denudation rates at the foot of the northern Babia Góra slope are very small in spite of the greatest mineral content in the waters in that area.

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Natural and artificial radionuclides as tracers of matter transfer in a rapidly deglaciating catchment

Arctic catchments have recently attracted increased attention because of the climatic changes that are expected to exert significant impact on these areas. Warming enhances glacier melt what leads to increased transport of sediment and solutes to the ocean. On the other hand, the retreat of glaciers exposes areas earlier covered by ice which can act as sediment sinks and can influence sediment transport to the ocean.

The Werenskiold Glacier (SW Spitsbergen) covers an area of 27.4 km^2 what constitutes 60% of the basin area of 44 km^2. Subglacial outflows from the glacier carry large amounts of fine suspended matter derived mostly from glacier-bed erosion. Only a few outflows collect material eroded under the glacier which must therefore represent all types of source rocks occurring in the catchment. Majority of this suspended material is transported to the sea but some fraction might be stored within the fluvial system of the proglacial area. Unsorted material is released from the glacier at its terminus and accumulated in the form of end and ground moraines. This glacial till is further reworked and redistributed in the proglacial area by outwash, solifluction, deflation or other geomorphological processes.

The aim of this study is to test and verify methodology for tracking transfers of fine matter in a deglaciating catchment and for assessing related time scales using the naturally and artificially occurring radionuclides. Natural radionuclides include some members of the uranium and thorium series (^{238}U, ^{232}Th, ^{210}Pb, ^{226}Ra, ^{228}Ra) and ^{40}K while the artificial radionuclides are Pu isotopes and ^{137}Cs released into the atmosphere mainly from nuclear weapon testing and various radiological incidents.

In its first stage the project is focused on the assessment of radionuclide levels in the primary sources of fine material (subglacial outflows, supraglacial melt-out till) and on identification of vertical patterns of radionuclide activity in sequences of fluvial deposits and initial soils. Radionuclide analyses will be supplemented by the granulometric and mineralogical observations. Preliminary results reveal some interesting features of radionuclide behavior in the studied system. Radionuclide activities are quite variable even in all types of analyzed materials what suggests some temporal and spatial heterogeneity in sources and pathways of radionuclide through the system. ^{226}Ra and ^{228}Ra are well correlated in the fluvial deposits sequences indicating a proportional release of the uranium and thorium series nuclides to the subglacial waters. On the other hand, ^{210}Pb is strongly depleted in these deposits comparing to ^{226}Ra what suggests that ^{210}Pb is preferentially lost from the weathered material in a dissolved form. ^{137}Cs, whose main inputs to the Arctic environment were nuclear weapon tests in the early 60's, is not abundant in the studied are but occurs with significant activities in some samples of supraglacial till as well as in some strata of the fluvial deposits and soils. Occurrence of ^{137}Cs indicates material contaminated by atmospheric radioactive fallout around 1963 and can be this used to trace its transfer through the catchment.

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Effect of the thickness and duration of snow cover on the date of appearance and stages of water in a basin without an outlet (the upper Parsęta catchment)

The article addresses mutual relations between meteorological and hydrological factors in terms of snow cover characteristics and their effect on the time of appearance and stages of water in a basin without an outlet.

Snow cover is a permanent element of winter seasons and an important climate-forming factor. It can be studied in a variety of aspects: meteorological, synoptic, hydrological, geomorphological, and economic. In meteorological studies, usually four basic characteristics of snow cover are examined: the dates of its appearance and disappearance, number of days it persists, and its thickness. In hydrology, five parameters are usually studied: snow density, snow water equivalent, water reserve, snow moisture, and snow quality.

When examining snow cover, one can also analyse the parameters of *fresh* snow cover. The appearance of the first snow cover is tantamount to the appearance *fresh* snow cover. As to the dates of the last appearance of *fresh* snow cover, they are usually a day earlier than the dates of the last appearance of days with snow cover.

The analysis covered data from the hydrological years 1999-2001 coming from the catchment of a closed evapotranspiration basin equipped with instruments, located in the upper Parsęta catchment. The dates of the appearance and disappearance of snow cover are described as well as the number of days it persisted and its thickness.

The most snowy winter in the period studied was that of 1998/1999. The highest maximum and mean thicknesses of snow cover were recorded then: 32 cm and 7.3 cm, respectively. Also the number of days with cover was the biggest - 75.

In accordance with the adopted thermal-rainfall classification, the years 1999 and 2001 were normal in terms of thermal conditions and precipitation totals, while 2000 was slightly warm and normal. 2000 was the warmest year of the three studied, and 2001 the coldest. As to annual precipitation totals, 2001 was the wettest year, and 2000 the driest.

In the first measurement year, water appeared in the depression in March, filled it the longest, for 5 months, and its stages were the highest. In the next hydrological year, water appeared in the basin a month earlier - in February, stagnated for only 3 months, and its stages were a bit lower. In the last observation year, there was no water at all.

Meteorological conditions were found to crucially affect the dates of the appearance and disappearance of snow cover and its thickness. In turn, the melting of the cover and the release of excess water has a very great effect on the kind, time and magnitude of alimentation of the closed basin; it also controls the matter cycle and energy flow in the geoecosystem under study.

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Use of dendrogeomorphological method in case of a small catchments study

In a small catchments most often don't exist any types of monitoring system. Therefore possibility of past events reconstruction are very poor. Important meteorological events could be reconstructed by comprising to the data from the nearest recording stage. Such a comparison usually mislead because long distance between catchment under study and measuring stage. Meteorological extreme events are strongly reflected in the geomorphologic features, so geomorphological study in small catchment are especially difficult.

In a forested catchments dendrogeomorfological reconstruction is very useful. Trees recording geomorphological past events in one year resolution. There are dozens of dendrogeomorphological works focused on tree ring analyse as tool for example erosion calculating. Most useful method of dendrochronological investigation of debris flow activity in mid-mountain are tree ring reduction analyses of wounded tree growing in the margin zone of debris flow trucks, this method should be either use to investigate morphology transformation of mountain stream. Trees growing along riverbed are wounded by transported coarse alluvium and record separate erosion episodes. Dating of logs laying under debris flow trucks are precise tool to investigate when the trees were fallen as an effect of debris flow occurring. Bank erosion processes are clearly recorded in exposed tree roots anatomy, especially in case of mountain steams. Bank erosion of meandering river should be explored by logs laying in the riverbed dating. Meandering rivers valley floor evolution can be precise reconstructed by trees dating growing on floodplain levels and paleochannels. Dating of roots exposure are accurate tool to gully erosion reconstruction. Additionally ring reductions of trees growing between hillslope and bottom of the old gullies under forest inform about erosion episodes.

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Hydrochemical processes in a headwater system (Pomerania, NW Poland)

The transition from a zero-order basin to a channel is referred to as a channel head and is one of the most important elements of headwater system. In the postglacial zone of north-western Poland (the Parsęta catchment), in a study area of about 618 km^2, 88 channel heads with groundwater outflows were identified. Seepage erosion and groundwater sapping lead to the development of channel heads in form of an oval niche or an arcuate alcove bordered by steep slopes. Steady groundwater outflows create conditions to the formation of first-order streams with discharges ranging from several to tens of dm^{3}s^{-1}, and as a result, to the development of fluvial processes. From among the headwater systems whose morphology and runoff volume are known to be connected with groundwater action, one was chosen for detailed study. The aim of this study is to identify the contribution of groundwater outflows to the formation of the river runoff and solute transport in a channel head.

The studied channel head embrace various groundwater outflows, including springs and less abundant groundwater seepages, located at the base and along the entire length of channel head slopes. Observations of water levels in piezometers show the water to respond quickly to precipitation, nourishing seepage zones from which rivulets flow down to the bottom of the depression or seeping directly from the banks of the headwater alcove.

Variations in specific conductance examined in piezometers and groundwater outflows on the slopes and bottom of the stream head indicate that the waters come from zero-order basin with various parameters and mix on the bottom of the alcove where the water attains a physical-chemical balance with the current atmospheric conditions. The differences in the chemical properties of water in the head area are due to two feeding sources: (1) groundwater in the saturated zone and (2) hillslope soil water. When the groundwater level was lower, only the two components affected the head water chemistry. When the groundwater level rose and the saturated zone spread, the groundwater in the transient saturated zone became the third component. With changes in soil wetness the level of water in piezometers settled in the zone of organic deposits, and the 'leaching' of substances accumulated in the top part of the soil profile. Groundwater outflows also have a significant effect on the mechanical properties of the substratum because they lead to disturbances in slope stability and mass movement. The hydrological and geomorphological processes play a key role in setting the direction of habitat-forming processes in the channel head.

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Small Catchments. Sediment yield and Urban Stability

Small catchments are considered as a dynamic system with a geomorphologic history, but, relation theses with urban stability is new. A small catchments and net work evolves with regard to uniformity climatic, lithology, and controls, and should be exist clear relations between catchments character and urban geomorphology.In the Small Catchments where land use, geology and runoff and climate are uniformity (similar), highly significant relations can be established between runoff and sediment yield. Important characteristic of small catchments is inverse relation between sediment yield pre unit area and drainage area. Urban development on the Small Catchments can be decrease sediment yield, then increasing stability. There are three main ways by which it is possible to gain response to urban.The first is to measure the comparative and direction of change of associated landforms. The second is to try to establish correlations between the features of spatially linked landforms and city. The third is to try to recognize of development and stability of cities.

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Challenges of small glaciated catchments monitoring

Guidelines of IAG/AIG Small Catchments Working Group delimit the area of its objects of interest in the range not bigger than 100 km^2. In the case of glaciated drainage basins this restrict the variety of studied catchments to some, that are holding separate medium and small size ice bodies, or outlet glaciers from larger ice-fields and ice-domes, with distinctly marked directions of ice-flow or topographic drainage divides. The uncertainty to determine such borders is the main problem projecting on further discharge and denudation calculations. First important task is than to detect subglacial topography and to recognize water circulation within the ice. This activity involves considerable means and efforts, through dense grid of boreholes or geophysical methods. The resolving of this problem would also probably give the answer to the question about glacier thermal conditions and the relation of glacier bed and the substratum. According to the bedrock coverage with ice it is also difficult to find out exact features of geological setting. Even in areas of homogeneous structures, some gaps may occur due to tectonics or pre-glacial soft sediment accumulation. Opportunities to explore subglacial channels or excavate artificial corridors are very rare. Some exertion as opposed to non-glaciated catchments is related to the definition of connections between glacial and non-glacial components of the outflow, depending on ice coverage in the catchment, dynamic state of ice masses, catchment morphology and various levels of water storage. Detailed investigations of these issues engage several methods:

- ✓ The ice-mass balance studies are performed according to observations of snow accumulation, its transformation and ablation of snow and ice against the stakes network installed on glacier surface, at least following the centerline with the interval of 500 m and every 50 m of height difference;
- ✓ The ice-flow velocity determination, based on ground-photogrammetry or geodetic and GPS measurements;
- ✓ The ablation examinations and modeling needs also much more intense grid of snow depth and albedo observations. Registration of meteorological conditions, is performed usually by automatic weather stations at two heights: equilibrium line altitude and near the ice snout. Common listing of measured parameters include air temperature, humidity, wind speed, wind direction, precipitation, radiation components (shortwave and longwave) and snow/ice conductive heat flux;
- ✓ Discharge measurements in a gauging station at the ice snout, in relation to its value at the catchment outlet (frequently supplemented by additional meteorological observations in this location to determine ice-free/vegetation-covered areas conditions). Differentiation between supraglacial/subglacial and surface/ground water input is also treated as an advantage. Temporary water storage might be examined using natural or artificial markers.

Nowadays monitoring of glaciers is usually supported with air- and spaceborn remote sensing methods, while analyzing snow and ice spreading and character, ice thickness changes and surface velocities.

Water outflow from glaciated catchments is commonly functioning in dispersed form, through a system of flat-bed, braided streams, with dynamic changes of the channels arrangement and bed-form migration. Proglacial water flowing with high energy is transporting a wide range of particles in suspension and traction. There, the discharge and material transfer are difficult to be precisely measured. Diurnal and seasonal fluctuations of water release, connected to morphologic alterations in the inundation zone, cause significant errors in denudation rate estimations. Only solid and resistant, regularly inspected gauging stations or very frequent measurements of channels profiles and water velocity field (once, twice a day during ablation period), might allow to avoid serious mispresentations.

Simple, one cirque glaciers, not larger than 20-25 km^2, located in well defined drainage basins, when well equipped and with a lot of effort invested, can be recognized as relatively good model study objects, reacting directly to rapid environmental changes and sensitive to meteorological conditions operation. In these cases continuous observations may isolate primary factors influencing the denudation system, what is not possible in a wide range of glaciers types of bigger size and complexity, where providing full range of investigations is very often problematic.

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Characteristic of Ebba Valley System (Central Spitsbergen) for catchment monitoring purposes

Ebba Valley System (EVS), oriented East-West, is extending widely on the eastern coast of Petunia Bay. In its upper part it is hosting the Ebba Glacier, which is both outlet and valley glacier, with complex system of feeding: as a branch of Mittag-Lefflerbreen, main stream outflowing from Lomonosov ice-plateau, and from individual accumulation fields located beneath nunataks Bastionfjellet (995 m a.s.l.), Jacksonfjellet (1127 m a.s.l) and Flemingfjellet (1125 m a.s.l.) and the ridge of McCabefjellet (980 m a.s.l.) in the massif of DeGeerfjellet (1024 m a.s.l.). The outlet tongue itself is flowing down to the valley between Wordiekammen (805 m a.s.l.) in the South and Hultberget (797 m a.s.l.) lower crest – Sporehogda (603 m a.s.l.) in the North. Another branch of Hulberget massif – Pukkelkammen (805 m a.s.l.), tending to NE, is enclosing located in the upper part of the valley small glacier Bertram, originating as well from Mittag-Lefflerbreen, between source areas of Ebbabreen and nearby located Ragnarbreen. Alimentation fields are rising. in the case of Ebbabreen to the maximum height of 1000 m a.s.l. and in the area of ice-divide with the main glacial stream to about 700 m a.s.l. The blurred contact situation is causing serious uncertainty in determination of catchment borders in this area. Following ice topography the Ebbabreen surface was measured to 20.4 km^2, while at the Little Ice Age (LIA) maximum it was 21.51 km^2 and Bertrambreen 3.81 and 4.36 km^2 respectively (Rachlewicz et al. 2007). The total drainage basin area, including the two glaciers supplying proglacial outflow, measured at the gauging station in the valley outlet, was determined as 51.5 km^2 (Kostrzewski et al. 1989). The Ebbabreen snout is actually located at the height of 120 m a.s.l., above the rocky threshold built of resistant metamorphic rocks, situated in the central part of the valley. This outcrop of rocks influences the longitudinal profile of the glacier, bending once more before reaching the accumulation zone with equilibrium line altitude estimated at the height of about 650 m a.s.l. The Bertrambreen is ending whole above the crystalline threshold, at the altitude 430 m a.s.l.

LIA marginal zone of Ebba Glacier, that started to be formed at the beginning of the 20^{th} century (Kłysz et al. 1989) is developed below and on the threshold of metamorphic rocks in the central part of the valley. Even in its axial part bedrock outcrops in form of mutonized surfaces are visible. Maximum height of morainic ridges is up to 20-25 m. This ramparts are intensively reworked due to mass-movements on its dead-ice cores. In front of both glaciers, mainly subglacially generated outflow, breaking through metamorphic threshold with spectacular waterfalls, is building the inner sandur plane. Lower in the valley, intense lateral influences of talus and outwash cones, extort the outflow channelizing in a single stream and significantly modify it with extraglacial (snow ablation and groundwater) input. The geology of EVS, according to Dallmann et al. (2004), reveals in the upper, steeper part that the glacier tongue is surrounded by metamorphic rocks, extending presumably continuously under the ice. Upper parts of the ice-field and the non-glaciated segments of the valley, following the general geological setting of this side of the bay, are built of huge Carboniferous - Permian sedimentary complex i.e. sandstones, shales, conglomerates, dolomites, limestones and gypsum/anhydrites. The distinct dimensions of the valley walls and slopes, the wideness of its bottom, is greatly influencing especially the non-glaciated segment. The EVS functioning is then representing not only variability of glacial environment, but in a very high grade reflect periglacial and paraglacial conditions, characteristic for the locally modified climate of the Spitsbergen inner-fiord area (Rachlewicz 2003a, Rachlewicz and Styszyńska in prep.).

Previous research in the EVS, concerning contemporary morphogenetic processes investigations, were carried by Adam Mickiewicz University in Poznań groups in 1985 (Kostrzewski et al. 1989) and between 2001 and 2007 (eg. Kostrzewski et al. 2003, Rachlewicz 2003b, Kostrzewski et al. 2007, Rachlewicz 2007, Rachlewicz et al. 2007). Apart from done temporary detailed geological, geomorphological and hydrochemical mapping as well as sediment sampling, the whole ablation season observations of meteorological conditions, discharge, solid and dissolved transportation in proglacial river were performed. Meteorological station is functioning at the level of the gauging station near the river mouth, supported by two automatic weather stations at the non-glaciated drainage divide and on the glacier at the equilibrium line altitude. Additionally basic glaciological parameters needed to mass balance calculations and ice-flow are registered. Basic observations of permafrost active layer and ground temperature, and since the summer 2007 ground-water dynamics and chemistry, are introduced (Marciniak, Dragon pers. comm.). The future task is to equip several profiles along the river course in automatic discharge and transport registration devices, and the standardization of measurements due to acknowledge guidance, as provided by Beylich and Warburton (2007).

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The fluvioglacial outflow and the transport of material in Ragnar river catchment

Close observation of the proglacial rivers work allows one to use the obtained results to paleodynamic interpret the sediments deposit the Pleistocene foreground of the glaciers in Europe. The Ragnar glacier catchment constitutes the north-east end of the Billefjorden (Central Spitsbergen). From the south-east the Ragnar river catchment is bordered by the Løvehovden and Hultberget massifs, and from the north by the Sfinksen and Gizehfjellet mountains. The lithology of the Ragnar catchment includes Precambrian and Devonian rocks, gypsum, anhydrite and sandstones. 44% of the area of the Ragnar catchment is occupied by glacier. The rest of the catchment make up: 54% rocky slope surfaces, 0.53% ground moraine plains, 0.42% solifluction slopes, 0.3% alluvial fans, 0.26% outwash plaine on bedrock, 0.06% talus cones *(own calculation on the basis of the map „Petuniabukta-Billefjorden-Spitsbergen, Geomorfologia" Karczewski et. all. 1990).* The specific polar continental climate of Petunia Bay features a short period of polar summer usually of 2-3 months' duration, higher temperatures during the ablation period, and very low rainfall figures throughout the year (Rachlewicz 2002).

In the summer 2001 the mean diurnal temperature was 6.8°C and the rainfall 38.1 mm. The estimation of the outflow size and the transport of material in the river catchment was enabled the 24-hour measurements of the flow rate and every day collecting samples of water for physiochemical analyses. Wolfe and English (1995) as well as Bartoszewski (1998) investigated the relations between the chosen meteorological elements and the outflow. They reported that the strongest relationship occurs between the outflow and the atmospheric temperature. During the research on Wedel's Land (Bartoszewski 1998) it was found that the best conditions for the flow approximation (r=0.9) to the atmospheric temperature occurred with the assumption that the temperature (T) for assigning the average daily flows is calculated as a weighted average of 0.7 the current temperature (t_0) and 0.3 the temperature of the previous day (t_{0-1}). It conforms with the author's observations.

Changes in the flow rate of the Ragnar river are delayed by 6 hours as compared to the fluctuations of the atmospheric temperature. This results from the time which ablation waters take to flow from the upper part of the Ragnar glacier. What is also significant is the ice-marginal lake which retains a part of the ablation waters. The research waters outflow measurement from the river catchment was combined with the denudation rate measurement and in the glacier ablation. The ablation measurement in the summer was conducted with the use of ablation poles. The Ragnar glacier ablation size was calculated from the decrease in the icecap thickness. The frontal part of the glacier featured the greatest average daily ablation (to 4 cm). Along with the altitude increase above the sea level the average daily ablation shows the decreasing tendency. The evaporation size was calculated from the dependence introduced in "Struktura materii ..." (1980).

The physical and chemical properties of glacial waters, particularly the suspension content and the general mineralization, enable one to infer about the hydrological processes and the dynamic processes connected with them, happening in the Ragnar glacier catchment inaccessible for direct research. The physical analysis of the water samples collected during the daily measurement of the flow rate allows one to qualify the quantity of the suspended and dissolved matter which left the investigated river catchment in the summer of 2001. The Ragnar river waters transported 464 tons of the suspended material and 1.3 tons of the dissolved material from the Ragnar river catchment. Total seasonal mechanical denudation rate c. 39 T km^{-2} and the chemical denudation c. 0.11 T km^{-2}.

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Multidisciplinary monitoring and modelling to understand the Holocene landscape evolution of a small upland catchment

The British Geological Survey (BGS) is undertaking a holistic multi-disciplinary study of a small upland catchment near Talla Linnfoots in the Southern Uplands, Scotland. The site, which covers about 3.5 km^2, is located on the interfluve between two major public water supply reservoirs northeast of Moffat. One of the aims is to develop an integrated 3-dimensional (3D) earth model of the site, which will lead to understanding landscape evolution within the catchment, in response to environmental changes during the past 12.000 years.

Geologically, the Talla catchment is dominated by glacial and periglacial deposits overlying resistant Ordovician greywacke bedrock. The valley fill comprises undulating moraines and blanket peat bogs, as well as narrow spreads of alluvium along Talla Water and its headwater tributaries. The lower valley sides are covered with thin colluvium mantling glacial till deposits; steeper rock slopes are mantled in scree.

The study consisted of three phases. The first comprised geological, geomorphological and soil surveys. These were followed by multidisciplinary site investigation of the shallow subsurface using several geophysical, geotechnical and intrusive techniques. This was followed by interpretation of the results and development of an attributed 3D geological model.

Characterising the ground was achieved using traditional site investigation methods such, as geological and soil surveying, trial pitting and borehole drilling, as well as light-weight penetrometer traverses. This was combined with an array of shallow geophysical techniques, including Ground Penetrating Radar (GPR) and Electrical Resistivity Tomography (ERT) were carried out between boreholes and pits, to gain additional continuous information on lateral extent and thickness of the geology to rockhead and provided a rapid, accurate representation of the shallow subsurface structure, where intrusive data was sparse. The catchment 3D geological model was constructed using “Geological Surveying and Investigation in 3D” (GSI3DTM) software. This utilizes a high resolution (1m cell size) Digital Terrain Model (DTM), created by terrestrial LiDAR survey, linked with mapped geology, borehole, auger hole and geophysical data, to form slices and sections. This approach enabled the geoscientists to construct regularly spaced intersecting cross-sections by correlating boreholes and the outcrops-subcrops of geological units to produce fence diagrams of the area. These can then be variably attributed eg by sediment type, chemical composition, geotechnical properties and permeability etc. Mathematical interpolation between the nodes along the sections and the limits of the units produces a solid model comprising of a series of stacked triangulated volume objects. Geophysical sections were used, as an additional data source, which enabled the interpretation of measurements in their true 3D positions and improved accuracy of the model along these traverses.

On-going studies at Talla include monitoring of shallow groundwater heads and water chemistry in instrumented shallow boreholes, with the eventual aim of establishing a linked model of shallow-groundwater movement and surface drainage through time. Adoption of this type of novel 3D geospatial modelling approach allows geoscientists to visualise, explore and interrogate the landscape evolution of small catchments, such as Talla in three dimensions. It can form an unrivalled template for catchment monitoring.

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Response of the channel to flood flows on example of the young-glacial small catchment of the Szeszupa river (NE Poland)

The upper Szeszupa river catchment is located in the Suwałki Lakeland (NE Poland). Its area equals 73,25 km and length of the river is 17 km. The upper Szeszupa represents a typical fluvial system of a young-glacial landscape. Along the course of the river there are melt-out depressions and melt water valleys connected with each other by gap and forming one river-lake system. Sinuosity of the Szeszupa river channel varies from 1,2 in water-gap parts of the river valley up to 1,55 in other parts of the valley. Mean inclination of the river is 3 ‰ but this value changes, similarly to the sinuosity, along the river course.

The aim of the research was to assess dynamics of fluvial processes with a particular respect to morphological variety of the river valley.

The field research was conducted in years 1987-89 and 1998-99. Water level, concentration of suspended and dissolved material were checked daily in 7 gauging points. Twenty six measurement series were obtained covering: rives discharge and concentrations of dissolved, suspended and bed-load. Geomorphological mapping of the river channel was performed after chosen flood event. The mapping was repeated in 2007.

Mean annual discharge varies from 0,18 m^3s^{-1} in the upper part of the researched channel up to 0,74 m^3s^{-1} in the lower part. Maximal discharge occurs during spring snow melt and reaches 0,65 m^3s^{-1} in the upper part and 2,4 m^3s^{-1} in the lower part. The snow-melt floods are not rapid and they usually last 10-14 days. The summer floods are caused by short-term downpours, usually 20-25 mm/day, rarely exceeding 30-40 mm/day and last 1-3 days.

The river valley morphology significantly determines fluvial processes. Higher concentration of suspended material was detected in water-gaps, where it reached from 80 up to 300-500 gm^{-3} during flood events. Beyond these parts of the valley the suspended material concentration was from 60 to 160 gm^{-3}. Snow-melt flood events caused side and bottom erosion. Accumulation occurred only locally and transported material constituted 25-35% of annual transport. High values of suspended and bedload material transport was detected during summer flood events but transportation effectiveness was relatively small. In many parts of the river, side erosion occurred near and simultaneously with accumulation on the channel floor.

The research shows that supply of sediment from the river catchment to the river channel is limited due to a large share of internal-drainage area (about 43% of the catchment area) and wide floors of melt-out depressions. Geomorphological mapping allowed to state that only 3-5% of the catchment area is a source of clastic material delivered to the fluvial transport. It follows that the main source of the material transported by the Szeszupa river is its own channel.

The research conducted in 1998-99 and repeated mapping of the river channel in 2007 showed differences in fluvial processes in comparison to the first period of the research. A change of weather conditions, especially occurrence of mild winters with no or thin snow cover, caused a decrease in river discharges during spring floods in comparison with years 1987-1989. Short-term summer flood events which play only limited role in fluvial erosion and transport are reflected in development of bimodal meanders and increase in sinuosity of the river channel. This process is best seen in melt-out depressions and melt water valleys.

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A short review of dissolved load estimation methodologies and a new proposal

Estimates of temporary and seasonal concentrations and loads of river solutes are a basis of many hydrological, geomorphological and ecological studies. They usually rest, not on continuous data registration but on the results of analyses of water sampled with a highly variable frequency. Commonly, the sampling interval is not adjusted to the hydrological characteristics of the object studied, but reflects an adaptation of typical methods to financial, technical and organizational possibilities (Littlewood, 1995).

Atmospheric deposition is monitored on a continuous or cumulative basis. It can be assumed - especially in the case of a small lowland catchment where spatial variability is negligible - that this mode of measurement guarantees the maximum possible accuracy of its estimation. Discharge measurement is different. Stream water for macro- and micro-component determination is sampled at weekly, bi-weekly or even monthly intervals. The accuracy of mean concentrations and loads of chemical components is therefore hard to estimate and, moreover, variable in time because it depends on discharge dynamics and the characteristics of a concrete catchment. Mean periodic concentrations are usually calculated using an average weighted in respect of discharge. To estimate temporary values, and in consequence to calculate the periodic mean, regression between the discharge and the concentration is usually employed. The same concerns loads. By restricting ourselves to regression only, we disregard the existence of a strong temporal autocorrelation between concentrations and discharges.

A comparison of the various methods of calculating the dissolved load transported in rivers is hindered by the lack of suitable reference data (Webb et al. 1997, 2000). The calculation is easier for the suspended load, because it is possible to use relatively accurate continuous nephelometric measurements of water turbidity (Webb et al. 1997). Webb et al. (2000) put forward a proposal for such an estimate based on the sampling of synthetic, *artificially*-generated measurement series of the concentrations of component solutes in rivers.

The principal aim of the present paper was to test alternative methods of the estimation of temporary concentrations of river solutes. Use was made of two-year series of diurnal measurements of the discharge and selected physicochemical parameters of the two catchments that present a contrast in the Polish conditions.

Seven series were derived from these data that simulated a week's sampling interval; next, by applying several numerical methods, the original daily figures were *reconstructed*. This approach allowed a comparison of the concentration estimation methods employed, both in terms of accuracy and, to some extent, precision. The comparison involved the results obtained with the help of regression with the concentrations plotted against the discharge (REG), linear interpolation (LI), three variants of spline functions (cubic spline CSPL, constrained cubic spline cCSPL, and local regression spline LRSPL), and geostatistical methods (ordinary kriging OK, simple kriging with varying local means SKlm, kriging with external drift KED, and co-located ordinary cokriging cOCK). To measure the quality of estimation, the coefficient of correlation, mean error, and mean square error were employed.

The data under analysis include two-year (1995-96) series of daily measurements of the discharge and selected physicochemical parameters of the upper Parsęta (73.4 km^2) and

Bystrzanka catchments (13.0 km^2). The former is typical of the lakelands of north-western Poland, and the other, of the Flysch Carpathians.

None of the tested methods can be considered universal and best under all circumstances. The results of the tests differ not only with individual parameters, but also with replicated series of measurements of the same parameter. A comparison of the results of calculations performed on only one reference set may lead to false generalizations. Equally significant is the type of statistical characteristics we need.

Generally, the worst method of interpolating measurement series of physicochemical parameters turned out to be regression with the discharge as an independent variable; possibly the most frequently used one. Its results were decidedly the worst in terms of accuracy. Also in terms of calculation precision, regression comes last on the list of the methods compared. Decidedly the best were the interpolation methods. This speaks volumes about the nature of the temporal variability of the composition of river solutes. The *direct* deterministic component connected with variations in the volume of water in the channel is of very little significance. Much more important are controls that can be termed hydrological and biochemical buffers of the catchment system responsible for the high temporal autocorrelation of the water's physicochemical parameters.

Co-located cokriging (cOCK) has ultimately turned out to be the best in terms of accuracy and precision, both when the additional variable is the discharge and specific electrical conductance (SEC). The algorithm shows its decided superiority in punctual estimation. The cOCK method also displays the least of the weakness common to all interpolation techniques: the flattening of the distribution of the estimated variable through an overestimation of the minimum values and an underestimation of the maximum ones. A promising direction in improving the performance of cOCK in estimation is its extension from the variant with two variables to one with more, including SEC or other water parameters whose automatic measurement can be conducted with little technical or financial difficulties.

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Spatial patterns of stream alimentation in lowland areas of NW Poland. A hydrochemical and geostatistical analysis

Areas of the Last Glaciation in northern Poland differ widely as to the conditions controlling the formation of river runoff and solute loads. The operation of even the smallest catchment in this area is very complex, owing to a poor organisation of the drainage system, a complicated geological structure of the Quaternary, diversified lithology, and a mosaic of land uses, including numerous water bodies and peat bogs. The characteristic features of the hydrology of this northern part of the Polish Lowland are a high proportion of areas with no surface outlet, a large retaining capacity of catchments and hence big hydrological inertia of streams, and the dominance of seasonal over short-term variability connected with rainfall or snowmelt episodes. The spatial and temporal variations in the conditions controlling the channel flow are reflected in a high variation, primarily spatial, of the unit flow modulus and the physico-chemical properties of waters. In small, even adjacent catchments, water mineralisation levels and solute loads can differ by more than one order of magnitude. That is why a hydrological interpretation of the channel flow in water-gauging profiles on those streams in terms of the identification of areas and ways of feeding is impossible without spatial studies and analyses. Apart from traditional hydrological mappings, a wealth of valuable data have been derived from hydrochemical profiling of the streams.

The aim of the research was to identify chief mechanisms of stream alimentation in this area depending on the scale of a catchment. The analysis rested on data from hydrochemical profiling. The study area embraces the upper Parsęta catchment with its diversified internal structure defined by the system of subcatchments. The catchment is situated in West Pomerania Lakeland. The studies were conducted in four subcatchments as well as in the entire catchment of the upper Parsęta. The catchment areas varied from 0.05 km^2 to 74.0 km^2, the length of streams, from 0.16 km to 13.26 km, and sampling intervals, from 2 m to 100 m. Mapping was carried out in periods of steady runoff, in a maximum of one day. The periods chosen corresponded to high water resources in the catchment, with all other forms of channel feeding beside the non-saturation (Hortonian) overland flow.

At the stream sites, discharge measurements were made using the dilution gauging method (Stach 1992). In addition to water sampling and discharge measurements, the water temperature, specific electrical conductance SEC (at a reference temperature of 25°C) and pH was also measured. Laboratory analyses of filtered water samples included:

- ✓ determination of the concentrations of calcium and chloride ions, calcium hardness and alkalinity by titration;
- ✓ measurement of the concentrations of sodium and potassium ions by flame photometry or atomic absorption spectrophotometry (AAS);
- ✓ spectrophotometric determination of the concentrations of sulphate and ionised silica; and,
- ✓ calculation of the magnesium ion contents.

In all cases the values of distances used in calculations and on the graphs come from direct field measurements along the studied streams channels.

The profiling data on the physical properties of water in the streams along their courses were analysed using geostatistical methods in order to identify their underlying spatial structure. The starting point for the geostatistical analysis is the calculation of an empirical semivariogram being a measure of the mean dissimilarity between measurement data separated by a distance **h**. The classical analysis of semivariance is intended for the study of series of stationary data, i.e., ones in which the deviation from the mean is random in nature. The analysed measurement series are non-stationary and there is often a strong tendency for water coming from upstream to "mask" changes occurring at a given point. In most cases the actual spatial structure of the analysed data can be discerned after the elimination of the tendency or the local average.

Three types of systems were found to occur: in spring-head catchments with areas of the order of 10^{-2} km^2, in small catchments (10^0 km^2), and in medium-sized ones (10^1-10^2 km^2). The first is connected with the mixing of soil- and groundwater, the second, with the mixing of waters from relatively homogeneous subcatchments, and the third, with the mixing of groundwater from various water-bearing horizons. In headwater catchments, river waters reach a new physico-chemical equilibrium at a distance of 20-40 m; in small catchments, two nested autocorrelation structures (150 and 400 m) reflect the sequence of land cover changes and distances between main tributaries; in medium-sized catchments, river waters demonstrate similarity at a distance of between 300 and 450 m and 1.2 km; it is controlled by the sequence of successive valley reaches of different origins (melt-out basins & ravines).The reported analysis justifies the hypothesis that in the areas of northern Poland covered by the Last Glaciation it is possible to identify the zones and forms of channel alimentation on the basis of hydrochemical interpretation of runoff recorded in gauging profiles only in the case of small catchments no larger than $n \times 10^0$ km^2. In larger catchments, it is only possible to differentiate between 'new water' (direct fall of precipitation on the channel and the overland flow) and 'old water', composed of a mixture of soil water and the alimentation from various water-bearing horizons.

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Monitoring of the upper Wieprz river catchment in the Central Roztocze region (SW Poland)

The Roztocze region is a low (300-400 m a. s. l.) ridge with character of horst, connecting the Polish and Ukrainian Uplands. It is built of upper Cretaceous opokas and gaizes, covered by Pleistocene loess in the western part, and Miocene limestone and sand in the eastern one. Apart from that, in central part, the Pleistocene fluvial and aeolian sand and Holocene silt and peat occur especially in the river beds. The plateau surface is cut here by a network of mainly dry valleys which depth amounts 100 meters. The average annual precipitation amounts 650-700 mm, average air temperature is 7-7,5 ºC and average time of snow cover – about 90 days. Poor river network is fed by efficient springs with waters of medium mineralization (200-300 mg/dm^3) with predominance of HCO_{3-} i Ca^{2+}.

The Central Roztocze region is drained by the Wieprz river. In its valley, there is a research station of Maria Curie-Skłodowska University in Lublin, located in Guciów village. The upper Wieprz catchment to the Guciów water-gauge occupies an area of 300.3 km^2. Among the surface deposits, loess and sand cover the largest area (each about 30%). Agricultural land use of arable land is predominant: arable land comprises 48% of the catchment, meadows – 11%, whereas forests – 33%. Ponds occupy about 1%. Since 1996 in Guciów, measurement of the Wieprz water level, suspended load and mineralization has been taken every day – according to them, outflow and denudation coefficients were estimated (Tab. 1).

Table 1. Mean monthly (1996-2006) precipitation and coefficients of the Wieprz river outflow and denudation rates of the catchment in Guciów

Coefficient	Measure	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	X	Year
Precipitation	mm	40	38	35	37	38	62	74	83	121	68	52	48	696
Discharge	m^3/s	1.11	1.07	1.12	1.36	1.98	1.96	1.24	1.12	1.17	1.20	1.23	1.25	1.32
Specific outflow	dm^3/s/km^2	3.7	3.6	3.7	4.5	6.6	6.5	4.1	3.7	3.9	4.0	4.1	4.1	4.4
Mechanical denudation	t/km^2	0.13	0.13	0.17	0.17	0.32	0.35	0.26	0.20	0.20	0.18	0.17	0.15	2.4
Chemical denudation	t/km^2	2.5	2.6	2.7	3.0	4.1	4.1	2.9	2.6	2.8	2.9	2.8	3.0	36.1

Amount of the upper Wieprz outflow coefficients and their not very high variability – both during one year and from year to year – is typical of Polish upland rivers, characterized by predominance of groundwater supply. However, rates of denudation – both mechanical and chemical – are low and typical for lowland ones. It is influenced by large participation of poorly soluble substratum rock, buffer meadow role which cover plain valley beds and small anthropopression intensity. However, within this catchment – including five partial catchments – and in neighbouring ones as well, clear variability of outflow and denudation coefficients is emphasized. Thus, system of eleven small catchments – of total area over 500 km^2 – has been controlled every week since 1998. They differ in geological structure, type of soils and land use. In 2003, automatic recorders of water level were installed in all research catchments.

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Chemical denudation in an young-glacial catchment (Chwalimski Potok, West Pomerania)

Headwater areas in the upper Parsęta catchment are the subject of multifarious research activities, concerning among others the determinants of chemical and mechanical denudation processes, the physico-chemical properties of waters circling in the catchment, the temporal variability of water chemism, the geomorphology of spring niches, the water erosion of soils, and the dynamics of flora. One of the prime qualities of young-glacial headwater areas are their small dimensions, which make it possible to simultaneously control numerous elements of the geoecosystem, ensuring the precise identification of its function.

The research programme executed in the Chwalimski Potok catchment (the upper Parsęta catchment, West Pomerania) has been devoted to an identification of the determinants, magnitude and spatial variability of the chemical denudation of the geoecosystem of the young-glacial headwater catchment.

The research was carried out in the hydrological years 2000-2003. The research procedure included hydrological observations and tests concerning the chemism of water at individual stages of circulation in the catchment. Monitoring covered precipitation, waters of the saturated surface runoff, infiltrating and drainage waters, subsurface runoff, groundwaters and surface waters. Additionally, research was performed into the physico-chemical properties of soils and deposits. Two experiments were also carried out: a laboratory experiment concerning the physico-chemical properties of effluents from soil cores subject to natural rainwater, and a field experiment consisting in the determination of the loss of mass of gypsum standards placed for a period of one year in the upper soil layer throughout the catchment area.

The Chwalimski Potok catchment cannot be easily distinguished against the backdrop of the morphology of the upper Parsęta catchment. This finds reflection in the structure of the free surface of groundwater, which points to a considerably greater area of supply than that covered by the watershed of the topographical catchment. The designated underground catchment area is 15 times greater than the surface catchment. An additional complication concerns the non-unidirectional drainage of waters from the underground catchment, which means that the application of the commonly used hydrometric method for calculating the chemical denudation of this area is not methodologically correct. In the present work, chemical denudation was determined by the outflow of water calculated on the basis of the water balance. The designated components of the balance were as follows: precipitation – 809.1 mm, evaporation – 425.1 mm, changes in retention – 4.5 mm, outflow – 388.4 mm. The value of chemical denudation obtained for the Chwalimski Potok catchment totals on average 120.8 t km^{-2} $year^{-1}$. The role of atmospheric deposits in chemical denudation is small. The aggregate ionic charge of atmospheric origin constituted only 3.7% of the charge channelled off by the streamway.

A factor which influences the reliability of the designated chemical denudation is the loss of constituents - very difficult to determine - which during the water transformation process are removed from circulation in the form of gas. The redox reaction occurring with the participation of micro-organisms within the riparian zone and hyporeic zone of Chwalimski Potok lead to the irreversible removal of large quantities of nitrates (up to 99%) and sulphates (up to 78%). The Chwalimski Potok catchment is particularly predisposed as regards the efficient reduction of concentrations of these components, due to the well developed near-stream saturated zones (these occupy approx. 13% of the catchment area).

On the basis of research into soil extracts and a laboratory experiment it was established that the areas of occurrence of rusty soils proper, deluvial humus soils and lessie weep ground gley soils are characterised by a low denudation potential, while that of ground gley soils is somewhat greater, and of peat-muck soils - the greatest. The spatially differentiated denudation potential of catchment soils remains concordant with the image of the spatial differentiation of the chemical denudation index obtained in the experiment with rock standards. The results show that the greatest quantity of material passes to the solution at points, in which there occurs the periodic full saturation of soil with water. In turn, the leaching process is rather ineffective as regards formations with high water permeability. The value of denudation indices, determined by the quantity of water and the time of its operation, implies the considerably more rapid lowering of the valley bed in relation to the lowering of slopes (even eightfold).

The determinants, magnitude and spatial differentiation of chemical denudation in the experimental Chwalimski Potok catchment was carried out using a number of different methods, from research into the physical and chemical properties of deposits and into the chemism of water at various stages of circulation in the catchment, to experiments performed in a laboratory and in the field. A consistent image of denudation processes was obtained. The results of tests made it possible to determine the correctness of functioning of the geoecosystem of the early glacial headwater catchment and to verify the method as regards research into chemical denudation.

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History of man-made denudation in agricultural catchment of West Pomerania (Perznica catchment, Drawskie Lakeland, Poland)

Human activity has played an ever more important role in the transfrormation of the natural environment. In areas where farming is the predominant land use anthropogenic denudation connected with land cultivation and animal husbandry is one of the principal factors modifying the operation of catchments and affecting relief development. The study of soli erosion by water carried out in the Parsęta catchment shows that in the morphgological-climatic conditions obtainedin the postglacial zone of West Pomerania, the magnitiude of mechanical denudation of farmland is primarily determined by the kind of crops grown and the farming practices employed (Klimczak 1993, Szpikowski 2003).

The investigation area - Perznica catchment - is typical, low urbanized, agricultural catchment of Drawskie Lakeland mesoregion, covering 245 km^2 and situated in the northen part of the Drawskie Lakeland. Its land-use pattern as well as the settlement and transport networks, and as a result man-made changes in the relief, are connected with the complex relief pattern whose basic elements include the subzones of plateau levels, thaw-hole landforms, dead-ice moraine, and kettle holes (Karczewski 1989). The results obtained so far show how important the cultivation of land has been in the formation of the denudation system of this postglacial catchment and allow the identification of stages of man-made denudation recorded in the morphology, lithology and soils of slope catenas (Szpikowski 2005a, 2005b, 2007).

The chronology of man's advance into and development of the Perznica catchment has been established on the basis of available data from the Materials of the Archeological Survey of Poland (resources of the Voivodeship Nature Conservation Officer in Koszalin) and archival maps (D. Gilly, *Karte des Koniglische Preussische Herzogthums, Hintern Pommern* - 1789; *Generalstabskarte GK* - about 1855; *Meßtischblatt*, topographic maps 1:25,000 - 1877 and the first half of the 20th c.; topographic maps 1:10,000 - 1980s).

The samples were taken during fieldwork from exposures dug in farming terraces (charcoal from fire-produced layers, organic material from fossil soil horizons of humus accumulation) and from boreholes in depressions located at the foot of scarps of the terraces (peats and gyttjas covered with mineral muds) had been radiocarbon-dated (in the Poznań Radiocarbon Laboratory). The results obtained was possible to identify periods of economic activity of the communities living in the Perznica catchment that can be regarded as history of man-made denudation (Fig. 1).

The rate of accumulation of the farming terraces in the period 1100-1600 AD it was about 0.2 mm a^{-1}, over the next 400 years (1600-2000 AD) it grew to 2-3 mm a^{-1}. The aggradation of farming terraces in the last 200 years attained to 6 mm a^{-1}.

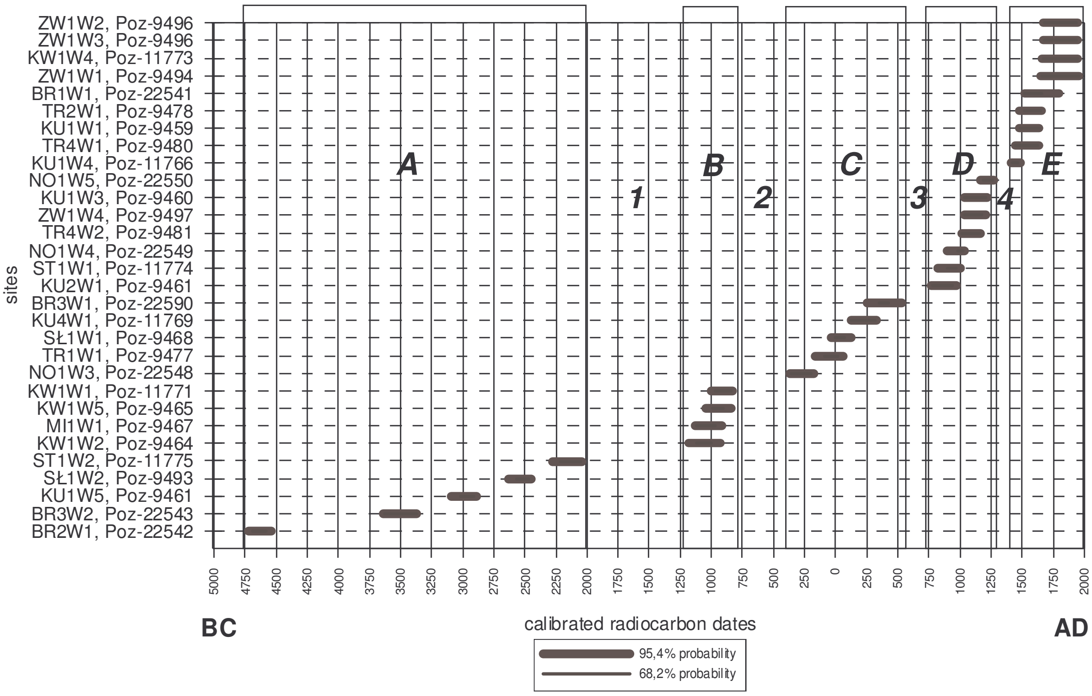

Fig. 1. Stages of man-made denudation on the basis of calibrated radiocarbon dates of sediment samples from the Perznica catchment. A – Eneolithic stage, B – Lusatian stage, C – La Tène-Roman stage, D – early medieval stage, E – medival and modern stage. 1 – early Bronze regression, 2 – Hallstatt regression, 3 – Migration Period regression, 4 – 14th-century regression

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Soil erosion and sediment supply to fluvial transport in a small agricultural catchment (Wiśnicz Foothills, Poland)

Carpathian Foothills cover 47% of the Polish Carpathians and 45% of the foothill area is used for agriculture. Therefore, soil erosion on slopes by water is one of very important geomorphic processes, which causes transformation of slopes' surface and significant damage to agriculture.

The research was carried out in the lowest part of the Carpathian Foothills, where the Field Research Station of the Institute of Geography and Spatial Management of the Jagiellonian University is located. The dominant type of relief are low hills and typical cover for this part of foothills are Quaternary loess-like formations.

The paper presents the results of research in Dworski Stream catchment, which is small (0.3 km^2), intensively farmed, with arable land covering 80% of the catchment area. The catchment is controlled by hydrometric profiles with flumes and a limnigraph. Since November 2006 soil erosion has been measured on seven plots. All the plots are 2 m wide but they differ in length (22.1 to 2.8 m). All the plots are closed with 2 m plastic Gerlach troughs. Water and material eroded from each plot are caught by the troughs and go into a separate water tank with a limnigraph. Out of the seven plots one is devoid of vegetation cover and is like arable land, one is grassland, one is a potato field whereas the remaining four, which differ in length, have wheat crops. The ploughed land and grassland will remain as such for the whole period of research (three years) while the crops on the remaining plots will alternate every year as it usually happens on agricultural farms in the foothill area.

The main aim of the research is to establish the intensity of erosion in relation to land use and explain the impact of rainfall parameters (amount, duration and intensity) on soil erosion. After each rainfall, measurements of surface flow and soil erosion are taken to allow comparing the intensity of the processes on plots which are differently used for agriculture.

The preliminary research shows that the soil erosion is is an occasional process. The rainfall of the same parameters, even within short and uniform slope plots, does not always bring about slope wash on every plot. The intensity of soil erosion depends mainly on the type of crops. Only sporadic short-duration and high-intensity rainfall events may trigger severe soil erosion causing serious loss of topsoil. The process leads to significant changes of the forms already present on the slope and to the formation of rills and gullies, and the material transported down the slope is accumulated on the footslope plains or in the valley bottom in the form of deluvial fans. Deposition of the material at the bottom of the slope and in the valley floor leads to the elevation and extension of the valley bottom and hindering transport of solid material from the slope to the channel. Consequently, slope-channel coupling and material supply becomes only local and episodic.

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Chemical transformation of precipitation in Gardno Lake catchment (Wolin Island)

The operation of the morphogenetic system of lake catchments should be considered in spatial-temporal terms (Kostrzewski 2003). In the contemporary denudation system of such catchments the physico-chemical transformation of precipitation plays a significant morphogenetic role. Of crucial importance for an insight into the operation of lake geoecosystems is to establish regularities underlying the transformation of the chemical composition of precipitation at the successive stages of the water cycle in a catchment, including throughfall, stemflow, groundwater, and surface water. Chemical differences of precipitation determine annual variations of the load of chemical substances introduced into slope covers, and play an important role in net denudation in the catchment (Kolander, Tylkowski 2007).

The Lake Gardno catchment is situated on the Wolin End Moraine in the Wolin National Park. What makes it unique is its seaside location in the immediate neighbourhood of the cliff coast of Wolin Island. The catchment covers an area of 265 ha and has no surface outlet (Kolander 2002, 2005).

Chemical variability were distinguished for the following stages in the water cycle: precipitation in open terrain, throughfall and stemflow, throughflow, groundwater, and surface water (Lake Gardno).

The transformation of precipitation is reflected in the hydrochemical type of water in the catchment. In the Lake Gardno catchment a rise in the mineralisation and reaction of water was observed at the successive stages of its circulation. The lowest mineralisation was recorded in precipitation in open terrain, with a mean concentration of 15 mg dm^{-3}. During its transition through the beechwood zone, its mineralisation level grew more than three times. For stemflow, the mean concentration of solutes equalled 48 mg dm^{-3}, and for throughfall, 50 mg dm^{-3}. On infiltration through slope covers, rainwater acquired substantial amounts of dissolved matter. Throughflow had a mineralisation level 11 times higher than rainwater, and its mean concentration of solutes was 161 mg dm^{-3}. In turn, groundwater had a mineralisation of 231 mg dm^{-3}, nearly 16 times higher than that of precipitation in open terrain. The highest concentration of dissolved chemical substances was recorded in Lake Gardno, at 243 mg dm^{-3}. Open-terrain precipitation in the Lake Gardno catchment was classed as water with a slightly acidic reaction - pH 4.82. At the successive stages of the water cycle, precipitation was observed to undergo alkalisation.

An exception was stemflow, which had a slightly lower reaction (pH 4.80) than precipitation. On infiltration through the soil profile, rainwater showed a rapid increase in the pH to 7.13 in the case of throughflow and 6.69 in groundwater. Lake Gardno was characterised by the highest reaction, at pH 7.50, which shows it to have a great buffering capacity.

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Sources and transformations of solutes in a glaciarised catchment

Polar glaciers of Svalbard have retreated considerably since 1920's uncovering large proglacial areas. Proglacial rivers collect the suspended and dissolved matter derived from subglacial erosion and weathering and convey this load to the seas. The highly dynamic proglacial environment might play some role in global biogeochemical cycling via impacts on riverine fluxes of dissolved matter.

The land-based Werenskiold Glacier in SW Spitsbergen covers 27.4 km^2 i. e. 60% of the catchment whose total area is 44 km^2. Two major subglacial outflows collect most of glacial melt water and as such provide an opportunity to monitor weathering processes and the associated solute fluxes from the glacierised part of the catchment. Observations of the physicochemical and isotopic properties of subglacial outflows performed in August/September 2007 showed a distinct response of these parameters to changing glacial melt intensity. Major weathering pathways seem to be carbonate dissolution and sulphide oxidation resulting in depletion of subglacial waters in O_2 and CO_2 but contributions from microbially mediated redox processes might not be excluded, at least at low flows. Development of a model of solute acquisition in the subglacial environment will require additional observations at various flow conditions.

Water properties of streams in the proglacial area undergo downstream changes due to mixing of different flow components (subglacial, supraglacial, active-layer groundwater) and due to in-stream transformations caused by: replenishment of dissolved O_2 and CO_2 from the atmosphere, chemical weathering and perhaps evaporation of water. Further insights into the nature of downstream evolution of the proglacial streams will be gained through the assessment of the properties of the active-layer groundwaters and through tracer experiments aimed at the evaluation of the hydraulic properties of the streams and their adjacent hyporheic zones.

The whole run-off from the catchment is finally collected by a single channel what provides an opportunity to monitor the quality and quantity of solutes leaving the proglacial area. Daily observations preformed over 4 weeks confirmed strong correspondence between water properties and flow rates. Effects of rainfall events were superimposed on the general trends related to gradually decreasing glacial melt intensity.

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Monitoring of Scottelva catchment (Spitsbergen) – methodology

Scottelva catchment is located in NW part of the Wedel Jarlsberg Land (Spitsbergen). It covers the area of 10.1 km^2 , 47% of which is occupied by the glacier that fills the valley. The glacier is the main source of alimentation. The research conducted within the glacial basin are of an interdisciplinary nature. The observations started in 2001 and with few intervals they are carried out each summer, since 2005 – continuously.

Research tasks include:

- ✓ <u>determining meteorological conditions</u> based on 4 automatic stations representing few different orographic location and topoclimatical conditions (marine terrace, Wijkandergerget, slope-foot Bohlinryggen). The scope of measurements includes the following meteorological factors: (1) temperature and relative humidity of air measured at the height of 200 cm and air temperature measured at the height of 5 cm over the surface of the ground; (2) temperature of the surface of the active layer (thermometer on the ground surface); (3) ground temperature at depths of 5, 10, 20, 50 cm; (4) amount of rainfall; (5) speed and direction of wind; (6) total radiation and UV (A+B) (7) air-pressure. Measurements are conducted automatically every 10 minutes, that is 144 times per 24 hours.
- ✓ <u>determining ablation, change of geometry and extension of fronts of Scott Glacier</u>. Measurements are conducted on the basis of the ablation stakes installed in selected areas and GPS receives. Readings are taken every 5 days. As a part of this task, also conducted are measurements of ice and snow density. That will allow for calculating the balance as a water equivalent.
- ✓ <u>determining the hydrological and hydrochemical conditions</u>. Tasks are conducted on the base of the measurements of the Scott Rivers' flow and state with hydrometrical grinder. The pressure sensor will be used within the lower river that closes the catchment. Simultaneously, water samples are taken daily for the laboratory analyses. To recognise conditions of the migration of the elements within the solution and suspension, there will be used analysis based on combining of measurement techniques: titrimetric, electrometric, spectrophotometric, chromatographic, and calculation methods – modelling by geochemical programs..

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Small catchments in polar regions

Global-scale changes like changes in temperature, biodiversity, land cover and so on, affect the functioning of the Earth System. High latitudes of northern and southern hemispheres are notably sensitive on that changes induced by natural processes and anthropogenic activity, too. Many reports and papers (ACIA 2004, IPCC 2002, Macdonald et al. 2003, NCDC 2005, Zwoliński 2007) emphasize some causes of this situation: exceeding of the hitherto absolute maxima of air temperature, an increase in annual precipitation totals (first of all in the form of rain, also during the cold period), cold periods becoming shorter and climatically milder, transitional periods becoming longer: spring comes earlier and autumn ends later, intense ablation and rapid recession of the majority of glaciers, a decrease in the area of nival covers, intensive thawing of the multi-year permafrost, changes in the land water cycle manifested by an increase in the surface runoff in streams and a shortening of the freezing period for streams and lakes in drainage basin, a growing area of surfaces saturated with meltwater from degraded buried ice-cores in marginal zones of glaciers, and a shift of geoecological zones in drainage basins. All of them generate much active fluvial environments in ice-free areas. Therefore, amongst the kinds of mineral matter trsnsition, a key role is played by fluvial material of different origin. The consecutive cascades of the fluvial system, i.e. of initial transformations, denudation, transport, redeposition and delivery, determine the system's internal structure.

On examples of different fluvial basins on Spitsbergen (Kostrzewski, Zwoliński 2003, 2007, Kostrzewski, Pulina, Zwoliński 2004), Iceland (Eraso, Domínguez 2005, Molewski 2005), Canadian and Siberian Arctic (WSAG 2008), as well as on Sub-antarctic Islands (Eraso, Domínguez, Lluberas 2003, Zwoliński 2007) will be formulate some properties for small catchments in polar regions. Small catchments define as an area (from 10^0 up to 10^2 km^2) drained by the stream/river system and spatially limited by an orographic water divide corresponding to a confluence or closing profile. For water circulation, six hydrological periods can be distinguished: mobile, transitional descending mobile, transitional descending immobile, immobile, transitional ascending immobile, and transitional ascending mobile. The dissolved material transported in streams shows two general tendencies reflecting the variability of the hydrological periods (Zwoliński 2007). The first tendency - a decline in specific electric conductivity - occurs in the first period of meltwater outflows. It is connected with the diluting influence of waters on the magnitude and concentration of the fluvial dissolved load, and with the surface runoff of dissolved substances after the immobile hydrological period during the transitional descending immobile and mobile periods. The other tendency - a rise in conductivity - is noted during the entire mobile hydrological period when the bedrock and sedimentary covers are intensively leached within the active layer of the multi-year permafrost. This allows much deeper penetration of surface waters into the bedrock where transformations of the throughflow and groundflow occur. These two distinct patterns of specific electric conductivity are observed in many catchments. The only differentiating feature is the time of their duration, which depends on the character and length of winter, ways of alimentation (glaciers, snow, permafrost), and the rate of snow cover decline. These tendencies are even better illustrated by the temporal variability of the concentration of the main ions in the stream waters. The most surface waters come from the zone of active water exchange, which means their communication with atmospheric water and a relatively short time of contact with bedrock and sedimentary covers. Thus these waters are fresh and young, staying in environments of high hydrochemical mobility and having no features of hydrochemical stagnation.

Concentrations of suspended material in the streams are characterised by high turbulence, fluctuations and irregular transport. Those observed in glaciated catchments are one order of magnitude (i.e. 10 times) higher than in non-glaciated catchments. The lowest, though also widely differing, concentrations of suspended material are noted for catchments with tundra cover. This can be connected with extensive marshes and lichens in the upper part of the catchments and a tundra cover in its lower reaches, which on the one hand capture and hold the suspended material, and on the other, add considerable amounts of suspended material of organic origin. As in the case of the transport of dissolved material, temporal duality can also be observed for suspended material in the streams. A bit larger concentrations of the suspended material are noted in the first half of the period of the surface water runoff, i.e. the hydrological transitional ascending immobile and mobile periods, i.e. at a time of snow-cover melting and mobilisation by the meltwater of fine particles on mineral surfaces. As time passes, the resources of particles accumulated and prepared for transport in the immobile period keep declining, and sometime in summer, the concentrations of suspended material are considerably lower. From the beginning of early autumn the magnitude of suspended transport gradually increases again, although still unevenly.

The hierarchical seasonality of fluvial activity is recognised as a main property for polar small catchment. The global variability of fluvial activity in such catchments is overlapped by seasonal and next diurnal variability. It corresponds to global, regional and local atmospheric fluxes and dynamics, atmosphere - land surface exchanges, changes in glacial mass balance and runoff, as well as to permafrost and ground water dynamics. These spatio-temporal features of polar basins are very common in polar and subpolar zones. Global variables are connected with such phenomena like ENSO or NOA, regional ones result from morphoclimatic zonality of high latitudes and even high altitudes in mountain areas and local variables are an effect of changes in morphogenetic domains, i.e. geosuccession form glacial to postglacial landscapes through paraglacial processes.

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FIELD GUIDE

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Wolin National Park, Gardno Lake experimental catchment, Environmental Monitoring Station at Biała Góra

Wolin National Park

Wolin Island, the location of Wolin National Park, is the largest island in Poland, covering the area of 265 km^2.

Wolin National Park is located at the estuary of Oder River, in the North-Western Poland, close to the Polish-German border. It protects highly valuable north-western part of the Wolin Island. The Park was established in 1960 on the area of 4844 ha. It was extended in 1996 by incorporating one nautical mile broad belt of Baltic coastal waters in the north and delta of Swina River. Inclusion of the part of Pomeranian Bay and inner salt waters of Szczecin Bay has made the Woliński National Park the first maritime park in Poland. The total area of the Park today is 10 937 ha, of which forests are covering 4530 ha (41%), six forest communities of a total area of 165 ha (1,5%) are under strict protection.

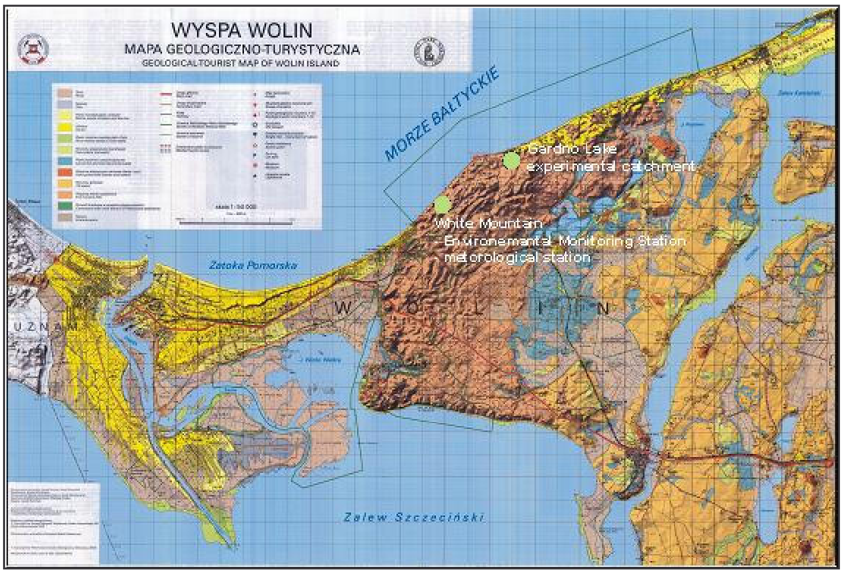

Fig. 1 Wolin Island – trip points (PIG, Warszawa 2004)

The origin of the oldest parts of Wolin is connected with the last ice-sheet action there. The main geomorphological unit of Wolin National Park and entire island is the Wolin Hills Range, extending from the Szczecin Bay towards the east from Lubin through Międzyzdroje up to Świętouść. The main axis of frontal moraine proves to have been S-N-NE direction. The Wolin frontal moraine appears partially or fully cut with several land depressions. In its eastern part the land depression is formed by a system of glacial channels, some of them filled in with lakes. On the north the surface of Wolin Island frontal moraine ends with a cliff, falling down towards the Baltic Sea. The Wolin frontal moraine exhibit the area with planty of remarkably diversified features. The altitudes within the Park are from 0 to 115 m. Moraine hills predominate in the relief, covering approximately 75% of the Park area. On the area of the frontal moraine are located places our field session: Gardno Lake experimental catchment, meteorological station and Environmental Monitoring Station at Biała Góra.

Fig. 2 Wolin frontal moraine – view from Grzywacz hill (115 m. a.l.s.)

The landscape of the Park varies greatly, including its most characteristic elements: 15 km long and up to 95 m high cliffs (Fig. 3). The cliffs expose the geologic structure of Wolin Island. The Wolin frontal moraine consists mainly of grey glacial diamicton (lower layer) and brown glacial diamicton (upper layer) and several top type sand and loam layers. Storms, wind and sun contribute to the cliffs' erosion. As a result they recede approximately 80 cm per year. The rate of coast recession depends on its geological structure. The destruction of the shore proceeds faster in the case of sandy deposits than those of glacial diamicton. The main reasons of the cliff sliding include: water underming of shores, dessication by sun radiation, deflation and rain washing-out as well as destruction by the trees falling or sliding down the cliff slopes.

Fig. 3. Cliff coast on Wolin Island (Gosań hill 95 m. a.s.l)

The climate of Wolin Island reveals a lot of features corresponding to the characteristics of the sea climate. The climate there is greatly affected by the direct neighbourhood of Baltic Sea but also by the fact that the area is under influence of transferring centres of low pressure from northern Atlantic towards the north-east of Europe. The above rationales decide about the great contribution of oceanic air masses in climate formation.

Waters, apart from forests, are predominating ecotypes of the Park. The northernmost part comprises a belt of Baltic Sea coastal waters and the western part - delta of Swina River. The delta is a complex of water-muddy islands, separated by channels extending in various directions of flow and with various water level, which are periodically overflown (especially during back flow, when Baltic waters, piled up by northern winds flow into the Szczecin Bay). The picturesque panorama of the delta can be admired from the top of Zielonka hill. The Park forests hide four post-glacial lakes: Warnowskie, Rabiąż, Czajcze and Domysłowskie, and artificial lakes: Turkusowe and Stara Kredownia (Source: Lewicka Ewa, Skrzypczak Marta "Woliński National Park – folder).

Gardno Lake experimental catchment

The Lake Gardno catchment is situated on the Wolin Frontal Moraine in the Wolin National Park (Fig. 4, 5). What makes it unique is its seaside location in the immediate neighbourhood of the cliff coast of Wolin Island. The catchment covers an area of 265 ha and has no surface outlet. Height differences reach 98.5 m. The area is fully forested, with a predominance of beech and mixed species (pine, oak, to a lesser extent spruce). The soils are largely podzols or podzolised and acidic brown soils formed mostly on fine sands. In the north-eastern part of the catchment, at an elevation of 16.9 m a.s.l., lies Lake Gardno with an area of 2.1 ha and a maximum depth of 6.9 m (Fig. 5). Lake belongs to a category of bottom moraine lakes with a bank line evolved. The mean annual air temperature (1996-2005) equals 8.7ºC, and precipitation 703.4 mm.

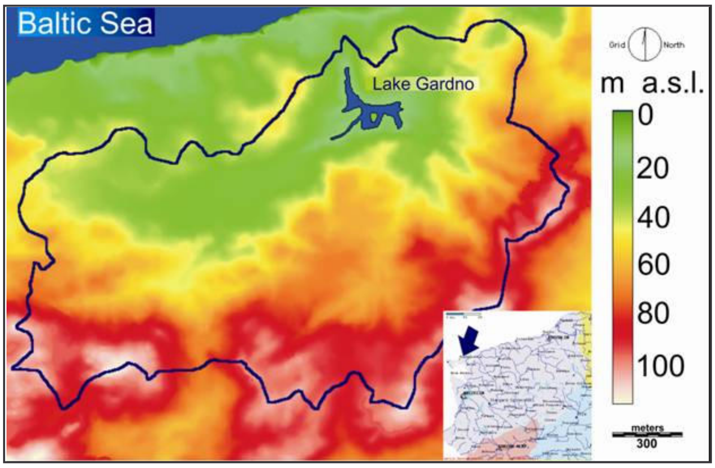

Fig. 4. Lake Gardno catchment on Wolin Island

Fig. 5. Gardno Lake

The Lake Gardno catchment has a research net (250 m^2) representative for the lake catchment, located in a Luzulo pilosae Fagetum forest community (Fig. 6). The monitoring embraced chemical properties of throughfall and stemflow (Fig. 7). The research net was established in the top part of the test slope. To ensure a better insight into the water cycle, a measuring site for throughflowing water was located in the bottom part of the test slope at depths of 30, 60 and 210 cm. The next stage of the water cycle embraced analyses of groundwater in two aquifers (5 and 7 m b.g.l.), in piezometers located on a lake terrace 40 m from the lake. The last measuring site was devoted to the chemical properties of Lake Gardno, sampled at one point at a depth of 0.5 m below the water surface. The measuring system of the Lake Gardno catchment belongs to the AMU Natural Environment Monitoring Station at Biała Góra.

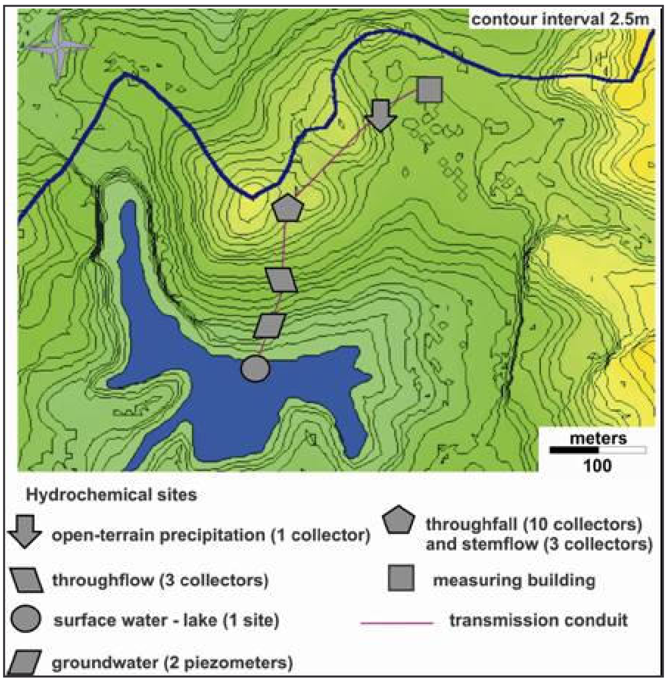

Fig. 6. Measuring system in the Lake Gardno catchment

Fig. 7. Measuring sites of throughfall, stemflow and lake waters - the Lake Gardno catchment

Environmental Monitoring Station at Biała Góra

The Evironmental Monitoring Station at Biała Góra is located on Wolin Island, on the area of Wolin National Park, about 2 km eastwards from Międzyzdroje. The Station operate since the year 2005. Earlier investigations were carried in the station at Grodno (1996-2004), 5 km eastwards from Biała Góra. The Station is ovned by Adam Mickiewicz University. Stations administrator is Geoecology Department. The Station consists of 3 objects (Fig. 8). Their total usable surface is almost 1000 m^2. There are rooms serving as: scientific (the hydrochemical laboratory, soil-sedimentological laboratory, computer room, lecture room), social (kitchens, bathroom, living rooms, rooms for creative work) and technical (garage, workshop, store-house of samples). The station possesses field investigative objects. This objects connected with environment monitoring system. The station can overnight 40 visitors.

Fig. 8. Building of Environmental Monitoring Station

The following scientific programs are running at the Biała Góra Station

- ✓ background and relations of present geomorphological processes (meteorological and hydrological monitoring),
- ✓ background, relations and present morphodynamics of morphogenetic processes on Wolin Island cliff coast,
- ✓ seasonal and spatial changeability of eolian deposition on coast Wolin Island,
- ✓ geoecosystems kelter present of young glacial forest interior catchment - current state, tendencies of development,
- ✓ meaning of atmospheric and aerosols sea chemical components for chemical denudation processes,
- ✓ participation of chemical and mechanical denudation for regional denudation,
- ✓ transformation of energy and matter circulation in different size and structure geoecosystems,
- ✓ meaning of extreme phenomena in processes: sea abrasion, fluvial, soils erosion and denudation,
- ✓ background, relations and seasonal variability of main morphogenetical processes in Polish coast zone of South Baltic,
- ✓ model studies of energy and matter circulation in geoecosystems of Wolin Island.

Main aims of carried investigations are as follows:

- ✓ recognition of mechanisms of circulation of matter processes in present geoecosystems of North-West Poland,
- ✓ recognition of conditioning and kelter of morphogenetical processes in different temporary and spatial scales,
- ✓ balancing of energy and matter flow in studied systems,
- ✓ the identification of long-term trends, the changes of use of terrain as well as quantity and quality of dirts connected with climatical changes,
- ✓ study of prognostic models of kelter geoecosystems in Wolin Island.

Station leads scientific investigations, organizes scientific conferences and field practices for students.

Meteorological Station at Biała Góra

The meteorological station in Biała Góra, situated on the Wolin frontal moraine, conducts the observation of weather elements in the neighbourhood of cliff coast (70 metres above sea level), (Fig. 9, 10). This is a first meteorological station on the Polish coast.

In the meteorological station in Biała Góra weather elements' observation have been carried since 2007:

- automatically - Milos 520 continuous record,

- manually - in accordance with the IMGW (National Meteorological Institute) standards - three times a day.

Fig. 9 Meteorological station at Biała Góra

Meteorological station – measuring programme:

• atmospheric pressure,
• air temperature 2 m above ground,
• air humidity 2 m above ground,
• total and strenght daily precipitation 1 m above ground,
• total daily precipitation at ground level,
• evaporation,
• wind speed and wind direction,
• solar radiation,
• insolation,
• air temperature 5 cm above ground,
• air temperature at ground level,
• ground temperature 5, 10, 20, 50, 100 cm below ground level,
• snow cover state and depth cm above ground,
• cloudiness,
• ground perfigeration,
• state of the ground.

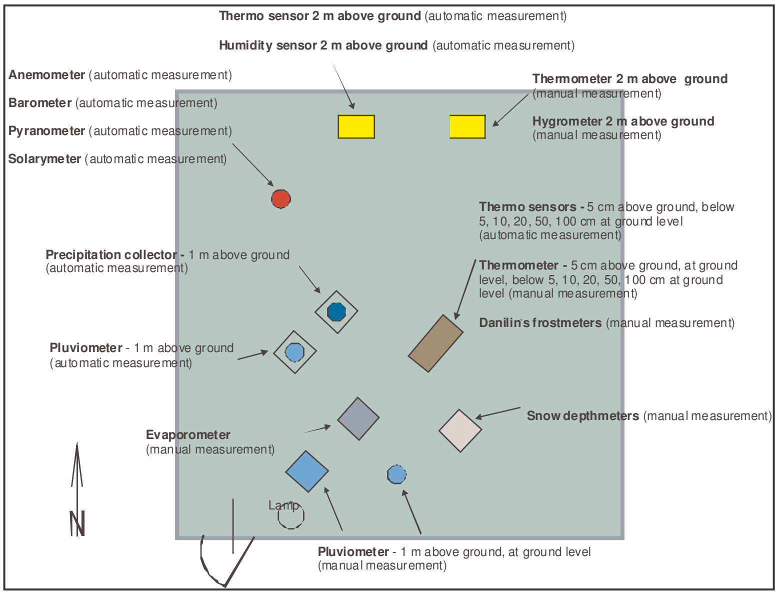

Fig. 10. Meteorological station – measuring apparatus

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